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FABRICATION OF MICROMETER LINE WIDTH SAW FILTERS USING DIRECT OPTICAL PROJECTION

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Projection printing directly on acoustic substrates using a 10X master and a high resolution 10:1 reduction lens in conjunction with the photoresist stripping technique has resulted in successful fabrication of micrometer line-width SAW filters, which are used in command, control, and communications and electronic sensing applications. This system and a typical 320 MHz (1.26μm line width) SAW filter are described in detail.

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Preface

Many requirements exist for high frequency, and therefore narrow transducer line width, surface acoustic wave (SAW) bandpass filters. These applications include command, control and communications (C^3), electromagnetic sensing, and electronic countermeasures (ECM). Until the present time, it was difficult to obtain masters for the fabrication of these filters. The procedures outlined in this report solve this problem by substituting a 10X master for the previously required 1:1 part. Thus, high frequency bandpass filters can now be made rapidly, reliably, and inexpensively.

At this time, the authors gratefully acknowledge many helpful discussions with Dr. P. H. Carr, and wish to thank him for his untiring support and encouragement.

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Fabrication of Micrometer Line Width SAW Filters Using Direct Optical Projection

1. INTRODUCTION

The rapid advances of surface acoustic wave (SAW) technology[1] to higher frequencies requiring line widths of the order of 1 μm in combination with large area (several mm) devices have taxed the capabilities of photolithographic reproduction to the utmost. The development of flexible glass chrome masks[2] has resulted in a reasonable yield in the reproduction of fine lines on SAW substrates when used in combination with the stripping technique[3] for photoresist. However, several problems persist with this technique. The thin glass (0.0075" - 0.0098") is difficult to work with, and the pressures used for intimate contact[2] can cause substrate surface abrasion or shattering of either the mask or substrate. In addition, extra processing steps are required to generate a mask. The technique outlined in this report eliminates these difficulties.

(Received for publication 27 January 1975)

1. Carr, P.H., (November 1972) Elastic surface waves — many new applications, AIAA J.(Am. Inst. Aeronaut. Astronaut.) 50-58.
2. Smith, H.I., Bachner, F.J., and Efremow, N. (1971) A high-yield photolithographic technique for surface wave devices, J. Electrochem. Soc. 118:821-825.
3. Smith, H.I. (1974) Fabrication techniques for surface-acoustic-wave and thin film optical devices, Proc. IEEE 62:1361-3187.

2. DIRECT OPTICAL PROJECTION SYSTEM

Direct optical projection[3,4] using a 10X master in conjunction with a high resolution 10:1 reduction lens has resulted in the successful fabrication of a variety of SAW filters having line widths as fine as 0.8μm. The stripping technique,[3] which is particularly suited for use with SAW crystalline substrates,[2] is maintained in our approach as opposed to work done previously.[5] That is, a positive photoresist (Shipley[6] AZ 1350B) is applied to an uncoated surface, and the substrate is spun at approximately 4500 RPM to achieve a uniform coating of 3800 A of photoresist (as opposed to 1000 A used in mask making[3]). It is then exposed and developed, and a metal deposition of 200-300 A of chrome plus 800-1000 A of aluminum is evaporated using an electron beam system with a source-to-substrate distance of 20".

Advantages of this procedure include (1) no mask to substrate contact, (2) no etching of the SAW substrate, (3) elimination of the 1:1 mask fabrication step, and (4) only a relatively inexpensive 10X reticle need be purchased. For example, to obtain a final device having 1.2μm lines, a master having only 12μm lines is needed. Such wide line structures are well within the capabilities of most commercial mask makers using computer-driven pattern generators.[3] The one disadvantage is the initial expenditure required (approximately $50,000, including translation tables) to set up a system. However, if a step-and-repeat camera is available, the initial cost of retrofitting the required lens, together with an illuminating UV condensing system, could be reduced to approximately $10,000. Surface flatness of the substrate is also significant. However, two-waves flat surfaces have proven perfectly adequate as the depth of focus is approximately 7μm.

The direct projection system, as illustrated in Fig. 1, consisted of a translation table from a D.W. Mann[7] No. 1080 step-and-repeat camera suitably modified to accept an available Ultra Micro Nikkor 1/10X E-Line lens and a mercury arc illuminator. The lens has a 650 lines/mm resolution capability. The 4mm image size of this lens is adequate for most high frequency SAW bandpass filters; however, it can be extended when necessary by reregistration, using an HP 5500A

4. Middlehoek, S. (1970) Projection masking, thin photoresist layers and interference effects, IBM Res. Dev. 14:117-124.

5. Mellon, D.W., and Bell, D.T., Jr. (1973) Development of a UHF surface wave pulse compressor, Proc. Ultrasonic Symp., 486-489.

6. Shipley Company, Newton, Massachusetts.

7. D.W. Mann Co., Burlington, Massachusetts.

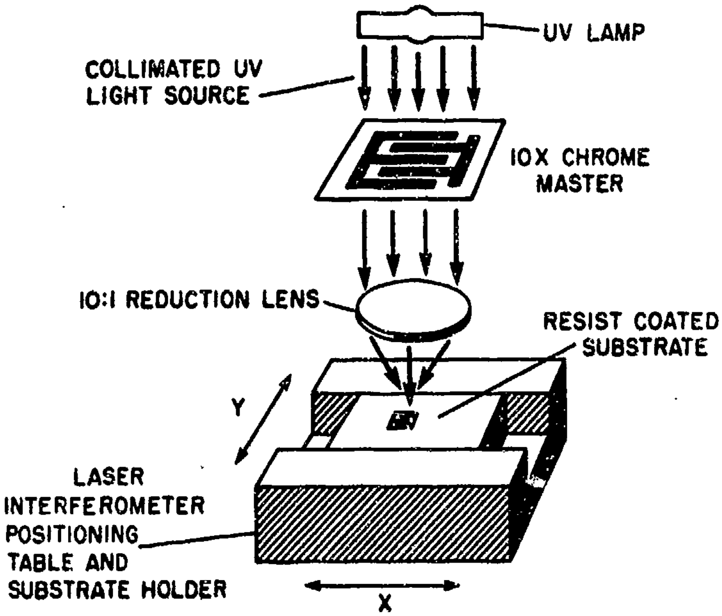


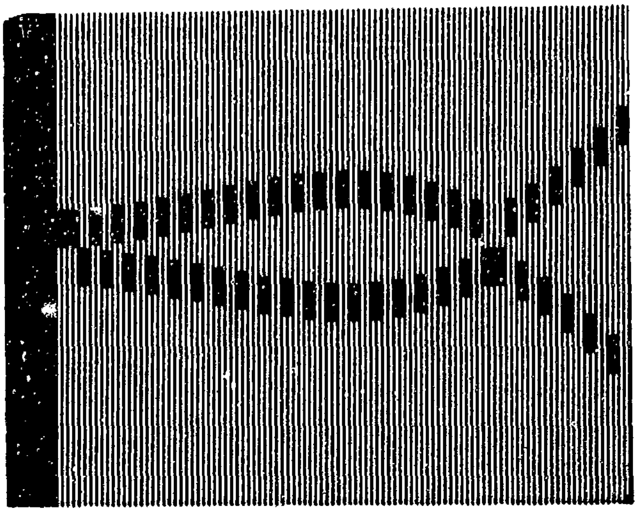
Figure 1. Schematic Drawing of the Direct Optical Projection System

laser interferometer.[8] The light source, based on the Kohler microscope principle, and optical train were integrated into a single unit in order to achieve the necessary alignment and stability. A precisely machined substrate holder referenced the image plane of the Nikkor lens to the substrate surface to tolerances of ± 0.00005. Optimum exposure of the photoresist was obtained by varying the intensity of the 200 W mercury arc vapor lamp using neutral density filters, and, of course, varying exposure time (typically ~4 seconds). Photographs of the fine line devices achievable with this system are shown in Fig. 2.

3. SAW FILTERS

As noted, the direct projection system described above has been used to fabricate a variety of SAW devices. A spectrum analyzer photograph showing the insertion loss versus frequency characteristics of one of these filters is

8. Hewlett-Packard Company, Palo Alto, California.



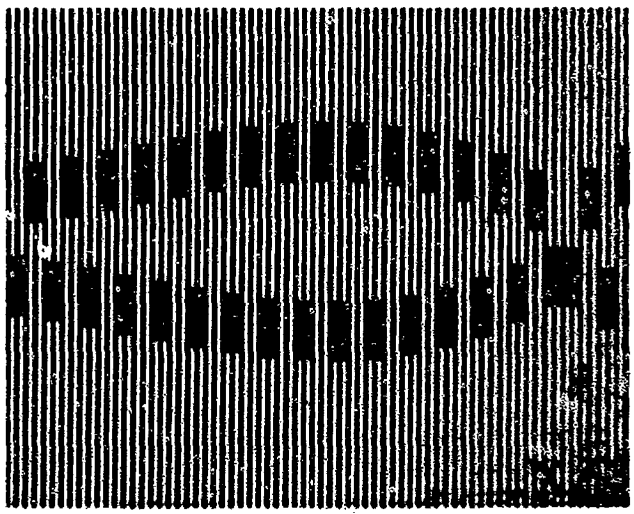


Figure 2. Microscope Photographs of Portions of Interdigital SAW Transducers Fabricated Using Direct Projection. Line Widths are 1.2um.

presented in Fig. 3. This design consisted of a Hamming weighted[9] cosine-squared-on-a-pedestal apodized transducer having 148 double electrode pairs used in combination with an unapodized transducer of 68 double electrode pairs.

9. Cook, C.E., and Bernfeld, M. (1965) Radar signals, Academic Press, New York.

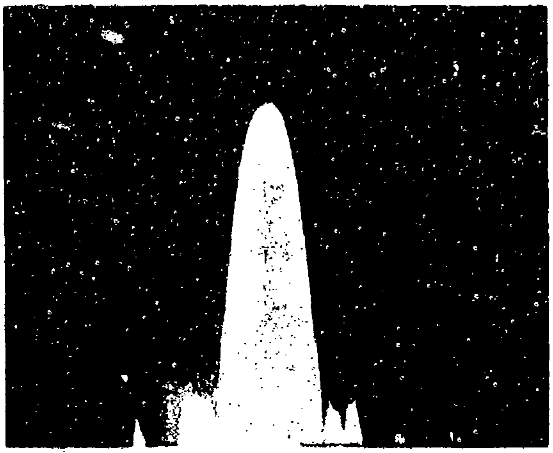


Figure 3. Insertion Loss Versus Frequency Characteristics of a YZ LiTa03 SAW Filter Fabricated Using Direct Projection. Minimum Insertion Loss is 16 dB. Vertical Scale: 10 dB/div With Top Line Corresponding to 0 dB. Horizontal Scale: 10 MHz/div With Center Line Corresponding to 320 MHz.

The diffraction corrected[10] Hamming weighting resulted in the low side lobes shown. This particular device is intended for frequency synthesis applications[11] in which a comb of frequencies separated by 10 MHz must be filtered. Overall insertion loss for this YZ $LiTaO_3$ device was 16 dB at 320 MHz, in excellent agreement with theory. No tuning inductors were used. The bandwidth between nulls of 30 MHz provided the necessary filtering action.

4. SUMMARY AND CONCLUSIONS

In summary, a new technique which is rapid, reliable, and inexpensive has been described for the fabrication of SAW devices. The excellent electrical performance of a 320 MHz SAW filter illustrated its utility. Lines as fine as 0.8um have been fabricated using this direct projection system. It is estimated that 0.5um lines are within the capabilities of the ultimate system (which will incorporate an Ultra Micro Nikkor G-Line Lens).

10. Szabo, T.L., and Slobodnik, A.J., Jr. (1974) Diffraction compensation in periodic apodized acoustic surface wave filters, IEEE Trans. Sonics Ultrason. SU-21:114-119.

11. Budreau, A.J., Carr, P.H., and Laker, K.R. (March 1974) Frequency synthesizer using acoustic surface wave filters, Microwave Journal, 17:65-69.

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